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CORNING GLASS WORKS

ELECTRO-OPTICS LABORATORY

RALEIGH, NORTH CAROLINA

# IMPROVED SCREEN FOR REAR PROJECTION VIEWERS

Technical Report No. - 15

Date - November 14, 1966

Period Covered - October 12, 1966

to

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TECHNICAL REPORT NO. 15

Technical Report No. 15 reports progress in the interm between Technical Reports No. 14 and 16. This is in keeping with our new schedule of making detailed technical reports bi-monthly and a brief summary report for the remaining periods.

I. Materials

A. Glass-Ceramics

We have obtained remelts of the two best samples found thus far, AC-18 and AC-19. For each of these two original samples we have five new samples each with a different heat treatment. These will hopefully give us a better feel for the optimum treatment. The samples are presently being prepared in our shop for measurement. We have also received micrographs of samples AC-18 and AC-19 which show particles in the desired size range. Data concerning number density is being computed. We have also obtained samples of 17 other glass-ceramic materials which are being prepared for measurement.

Because of the importance of being able to fabricate prototype models of rear projection screens with realistic dimensions, e.g. 6" x 6" to 12" x 12", new investigations along this line are being initiated. We are anxious to have some practical screens of AC-18 and AC-19 material as soon as possible.

B. Fotoform® Glass

Our investigations of the optical properties of the material with the scattering layer are continuing. We have shown that the thickness of this scattering layer can be reproduced to within about ±6%. We have also prepared three different prototype rear projection screens of this material.

A series of investigations of etched lenticular surfaces is being planned. This will involve exposing a master pattern into a piece of Fotoform® glass and then etching out part of the pattern. This master pattern will consist of opaque and transparent bars 75 microns wide where $I_{max}$ and $I_{min}$ represent maximum and minimum values of screen brightness within a $\pm 45^{o}$ viewing angle. Thus, V is the ratio of the greatest deviation of the intensity from the mean intensity. Consider the values of $T_{45}$ for the Corning materials as a function of axial gain, Table I and Figures 1, 2, & 3. We find values very near the theoretical curve which is based on single scattering by isolated particles. However, because of the steep slope of the curve some error is still present. Nevertheless the agreement is still quite good except for 3 or 4 poor samples. On the other hand, for the commercial materials only 3 or 4 are near the theoretical curve, Table II and Figure 4. On the average the rest of the materials should be at least 50% more efficient, i.e. at least 50% more of the incident energy should appear within the viewing angle of $\pm 45^{o}$. The best commercial materials based on $T_{45}$ data are SN-2149, TR-50PL, and S-50R which are 78%, 78%, and 69% of the theoretical limit, respectively. Table II gives this data for all of the commercial materials. Compare these with Corning samples AC18A, AC18B, AC19B, which are 83%, 86%, and 95% of the theoretical limit.

Next compare the brightness variation of the three previously chosen commercial screen materials with the goal of $\pm 15\%$ variation within a viewing angle of $\pm 45^{o}$. From the data of Table II we see that the brightness variation of these are $\pm 3.9\%$, $\pm 23.8\%$, and $\pm 40.9\%$ respectively. Again we see the SN-2149 being very uniform while the other two materials exceed the maximum limit of $\pm 15\%$ by $\frac{23.8 - 15}{15} = 59\%$, and 167%, respectively. The Corning materials have brightness variations of $\pm 1.5\%$, $\pm 13.7\%$, and $\pm 2.8\%$, all well within the established limits. These data are summarized in Table III. From this data we see that most

Table III

| Sample Code | Axial Gain | $T_{45}$ % | V ±% |
|---|---|---|---|
| AC18A | 1.6 | 23 | 1.5 |
| AC18B | 2.5 | 30 | 13.7 |
| AC19B | 1.9 | 27 | 2.8 |
| SN2149 | 1.2 | 17 | 3.9 |
| TR-50PL | 2.4 | 27 | 23.8 |
| S-50R | 3.7 | 31 | 40.9 |

and made on a 3-inch-square piece of ultraviolet-transmitting glass. By not using a perfectly collimated light source and by not placing the mask and the Fotoform® glass in contact, a nearly sinusoidal pattern can be exposed into the sample.

We have obtained one sample of a specially prepared glass which has a 100-micron-thick surface layer containing metallic particles. However, our analysis indicates the metallic particles are too small. Further samples of this material will be made.

Pulling of the large lenticular plate into ribbon has been delayed. Work on this is scheduled to begin again the first week of December. The required techniques for drawing such a piece of glass have already been tested.

## II. Instrumentation (MTF Analyzer)

The electronics of the modulation transfer function analyzer have been completed. We are now in the process of installing a precision lead screw and nut in the film transport. Except for the mask, this will complete the MTF analyzer. A new series of medium contrast masks will be made during the last two weeks of November. We will then be regularly reporting MTF data on rear projection screens.

## III. A Comparison Between Commercially Available Projection Screen Material and Those from Corning Glass Works

The question of whether any of the CGW materials are significantly better than materials commercially available can only be answered in part, because as yet, we do not have MTF data on the materials and, secondly, the term "significant" is not well defined. What we intend to do is to compare the materials from Corning Glass Works with those rear projection screen materials commercially available based on the data which has been regularly reported in the past.

To make this comparison we shall use two measures: the fraction of the incident energy inside $\pm 45^{\circ}$, $T_{45}$, and the brightness variation, within $\pm 45^{\circ}$. The brightness variation, V, is computed from the relation

$$V = \pm \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

of the commercial materials do not scatter all of the possible light into the $\pm 45^{\circ}$ viewing angle even though they have higher axial gains; the Corning materials however are performing much nearer the theoretical limit. Also the commercial materials give considerably greater variations in screen brightness than do the Corning materials. It is interesting to note that only one of the 27 commercial materials has a value of brightness variation within the $\pm$15% limit. We again return to the question; are these improvements significant? Probably only after MTF data are available under various levels of ambient illumination can this comparison be completed with any assurance of validity. However, the advantages of the Corning materials are consistent; meaning that samples of CGW screens can be fabricated which cover a variety of optical requirements and all can be expected to perform at near to the theoretical performance limit without making as large of trade offs between efficiency ($T_{45}$) and brightness uniformity as the commercial rear projection screen materials.

Table I

Summary of the Optical Properties of Some Corning Glass Works' Materials

| Sample Code | $T_s$ % | $T_{45}$ % | $T_{spec}$ % | Axial Gain | Brightness Variation $\pm 45^{\circ}$ (%) | Thickness mm |
|---|---|---|---|---|---|---|
| AC-1A | 37. | 15. | 36. | 1.2 | 15.6 | .534 |
| AC-1B | 40. | 17. | 19. | 1.3 | 10.5 | .915 |
| AC-3A | 64. | 25. | 10. | 8.3 | 68.2 | .483 |
| AC-3B | 60. | 26. | 4.8 | 2.4 | 15.5 | .787 |
| AC-10A | 69. | 27. | 4.8 | 1.9 | 4.85 | .534 |
| AC-10B | 55. | 23. | 7.2 | 1.6 | 1.5 | 1.287 |
| AC-11A | 25. | 16. | 57. | 11. | 91.7 | .368 |
| AC-11B | 79. | 29. | 19. | 17. | 81.4 | .825 |
| AC-12A | 38. | 14. | 3.6 | 0.98 | 3.6 | .610 |
| AC-12B | 39. | 15. | 4.8 | 1.0 | 2.6 | .623 |
| AC-15B | 53. | 21. | 14. | 1.5 | 4.7 | .991 |
| AC-16A | 59. | 24. | 24. | 1.8 | 11.5 | .376 |
| AC-16C | 52. | 20. | 7.2 | 1.4 | 3.2 | .864 |
| AC17A | 46. | 17. | 14. | 1.2 | 2.0 | .534 |
| AC-17B | 35. | 13. | 12. | 0.88 | 2.1 | .929 |
| AC-18A | 61. | 23. | 3.6 | 1.6 | 1.5 | .864 |
| AC-18B | 76. | 30. | 2.4 | 2.5 | 13.7 | .356 |
| AC-18C | 66. | 25. | 0.0 | 1.7 | 3.57 | .533 |
| AC-19A | 59. | 22. | 4.8 | 1.5 | 1.2 | .85 |
| AC-19B | 73. | 27. | 3.6 | 1.9 | 2.8 | .33 |
| AC-19C | 44. | 16. | 0.0 | 1.1 | 2.5 | 1.05 |
| AC-19D | 62. | 23. | 0.0 | 1.7 | 4.75 | 0.572 |
| AC-20A | 52. | 20. | 3.6 | 1.4 | 3.7 | .623 |
| AC-20B | 48. | 20. | 2.4 | 1.4 | 4.7 | .864 |
| AC-21A | 55. | 21. | 26. | 1.5 | 3.8 | .457 |
| AC-21B | 56. | 21. | 19. | 1.6 | 5.8 | .965 |
| AC-24A | 46. | 18. | 29. | 1.5 | 10.3 | .521 |
| AC-24B | 53. | 20. | 12. | 1.4 | 2.8 | .940 |
| AC-26B | 67. | 27. | 7.2 | 2.1 | 11.6 | .864 |

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Table I (continued)

| Sample Code | $T_s$ % | $T_{45}$ % | $T_{spec}$ % | Axial Gain | Brightness Variation ±45°(%) | Thickness mm |
|---|---|---|---|---|---|---|
| AF-1A | 28. | 11. | 43. | 1.1 | 23.7 | .534 |
| AF-1B | 41. | 15. | 24. | 1.3 | 13.0 | .991 |
| AF-2A | 46. | 22. | 19. | 1.9 | 17.7 | .521 |
| AF-2B | 36. | 12. | 4.8 | 0.93 | 6.5 | .965 |
| AF-3A | 42. | 20. | 14. | 1.9 | 25.6 | .534 |
| AF-3B | 40. | 14. | 4.7 | 1.1 | 7.5 | .991 |
| AF-4A | 37. | 20. | 4.7 | 1.9 | 26.6 | .534 |
| AF-4B | 27. | 10. | 2.4 | 0.8 | 2.6 | .991 |
| AG-1A | 34. | 12. | 0.0 | 0.9 | 1.4 | 0.584 |
| AG-1B | 38. | 14. | 0.0 | 1.0 | 2.56 | 1.016 |
| AG-2A | 24. | 8.6 | 0.0 | 0.6 | 0.08 | .584 |
| AG-3A | 25. | 9.2 | 0.0 | 0.7 | 3.38 | .584 |
| AG-4A | 66. | 25. | 0.0 | 2.1 | 12.6 | 1.016 |
| AG-4B | 81. | 34. | 0.2 | 3.5 | 29.2 | .559 |
| AH-1A | 40. | 15. | 0.0 | 1.0 | 1.53 | .965 |
| AH-1B | 58. | 22. | 0.0 | 1.5 | 1.75 | .467 |
| AI-1A | 62. | 24. | 0.23 | 1.7 | 4.61 | 1.074 |
| AI-1B | 34. | 12. | 1.47 | 0.9 | 6.88 | .559 |
| AI-2A | 32. | 12. | 0.0 | 0.8 | 0.99 | 1.016 |
| AI-2B | 42. | 16. | 0.0 | 1.1 | 3.58 | .546 |
| | | | Fotoform® Glass | | | |
| AD-15 | 94. | 71. | 0.0 | 113.0 | 98.5 | .106 |
| AD-17 | 88. | 43. | 0.0 | 7.1 | 55.3 | .168 |
| AD-19 | 80. | 33. | 0.0 | 2.4 | 9.86 | .322 |
| AD-21 | 92. | 44. | 0.0 | 4.1 | 27.9 | .286 |

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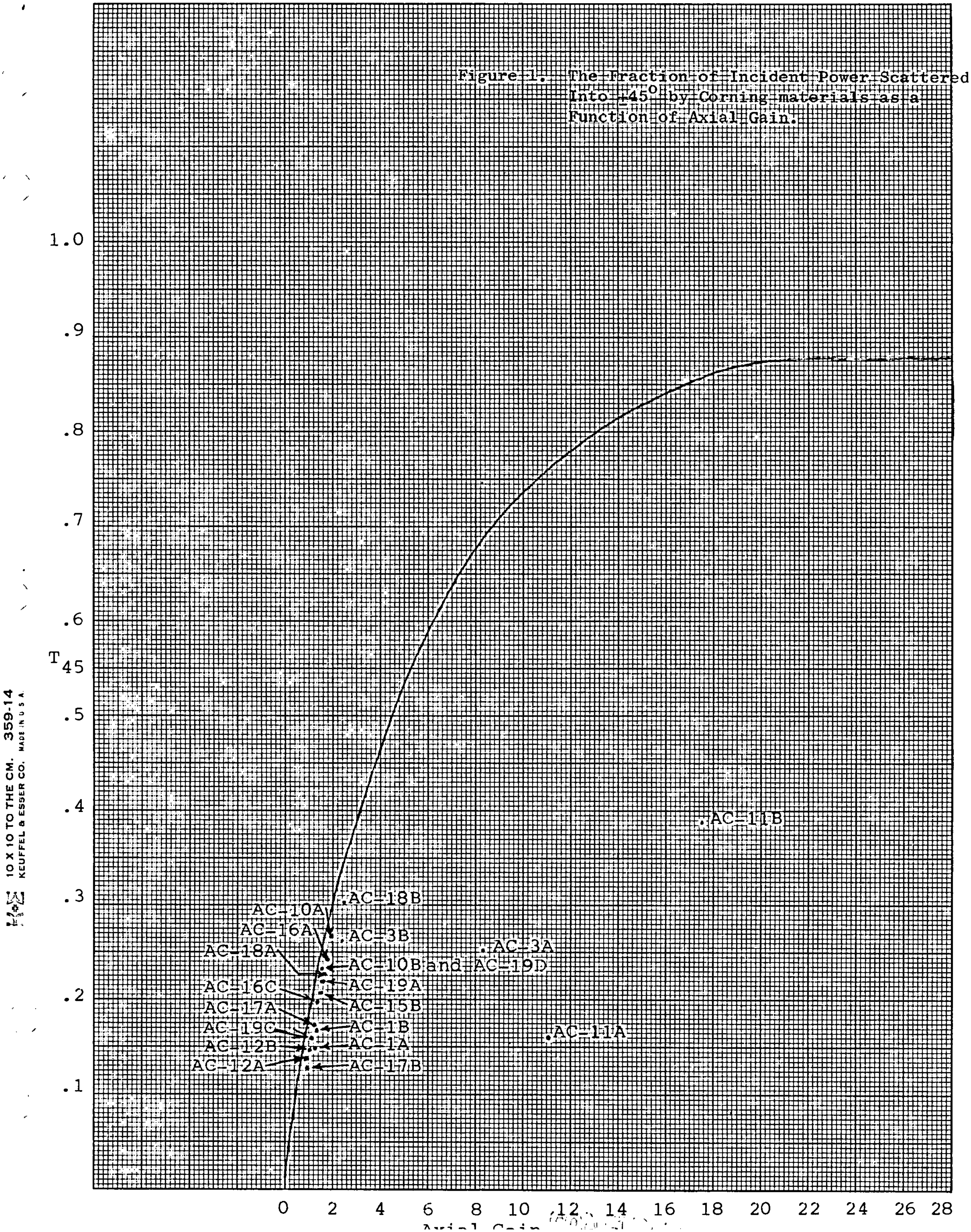



Figure 1. The Fraction of Incident Power Scattered Into ±45° by Corning materials as a Function of Axial Gain.

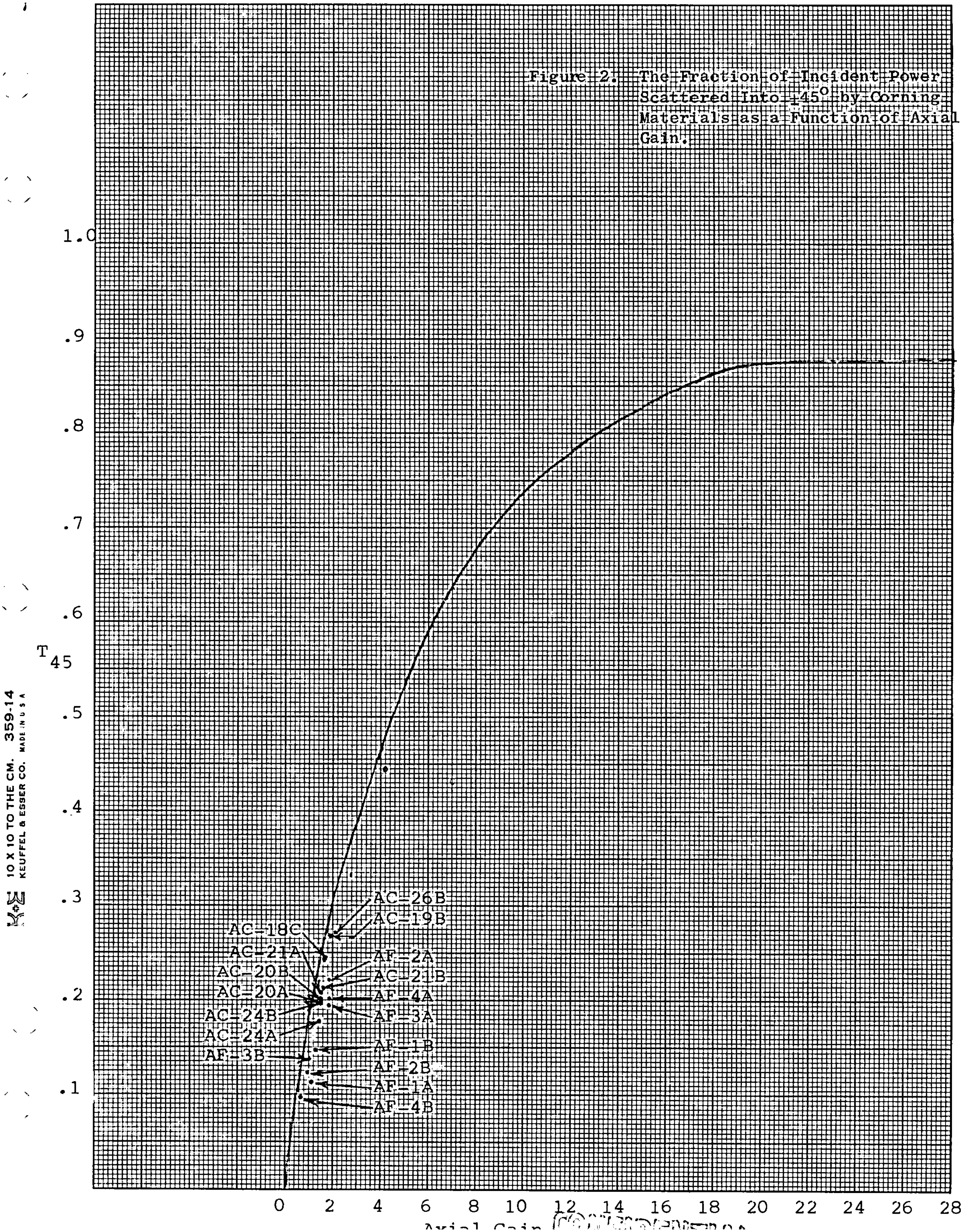



Figure 2. The Fraction of Incident Power Scattered Into $\pm45^{o}$ by Corning Materials as a Function of Axial Gain.

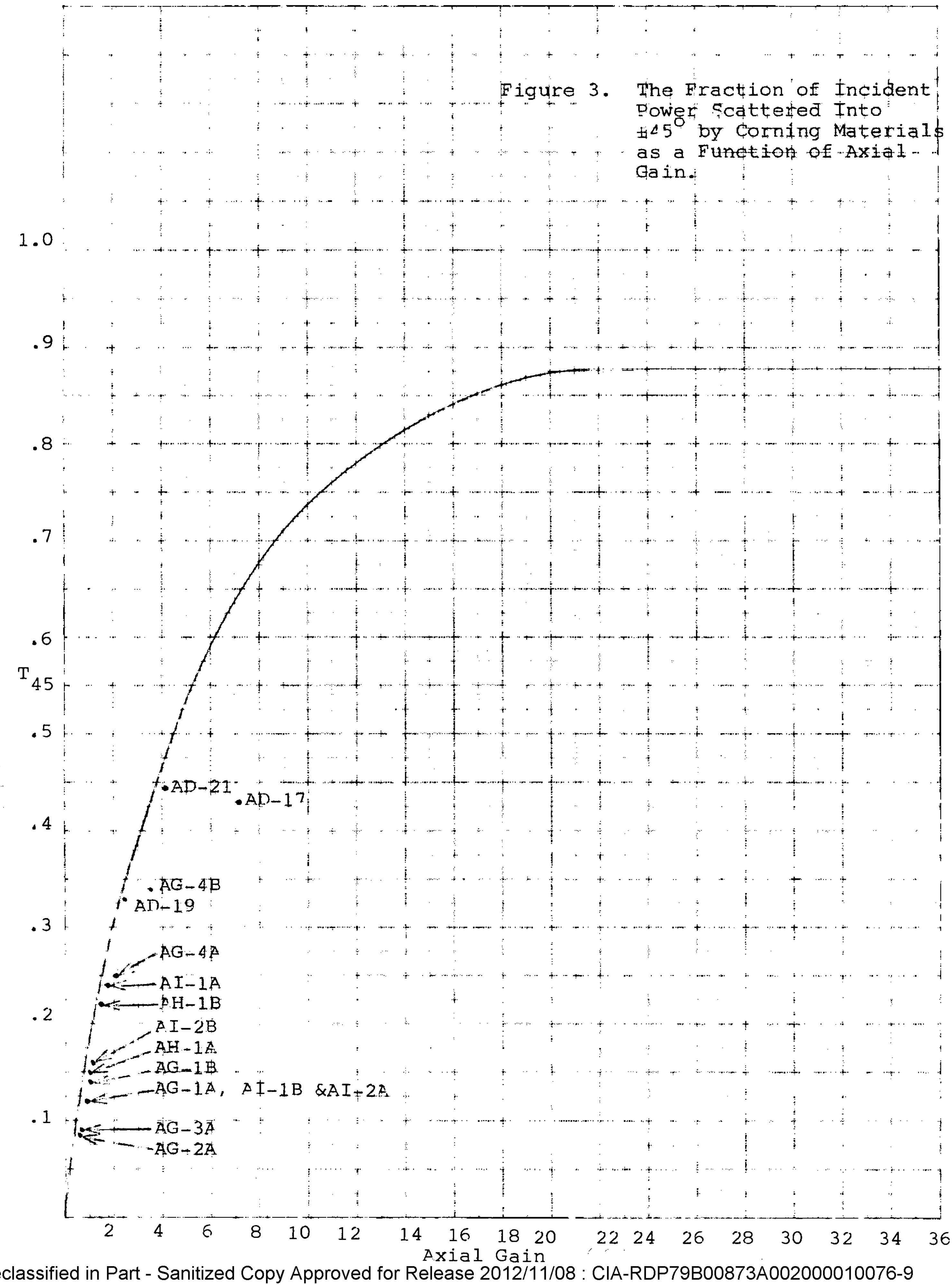
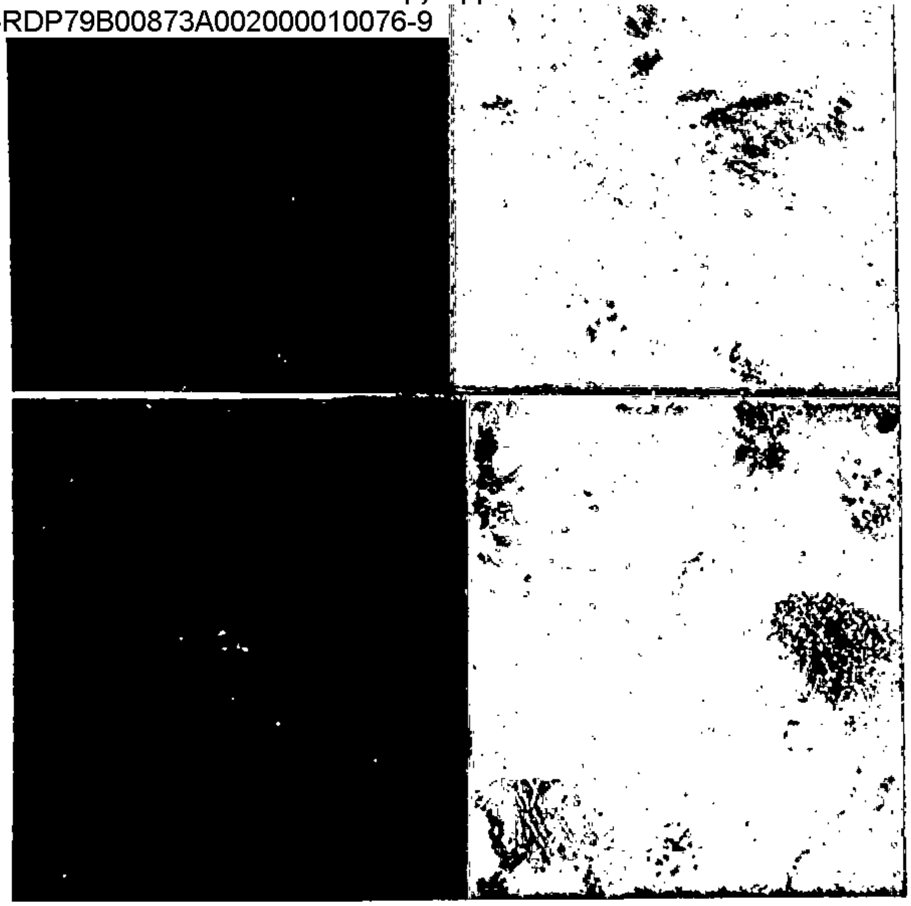



Figure 3. The Fraction of Incident Power Scattered Into $\pm 45^{o}$ by Corning Materials as a Function of Axial Gain.



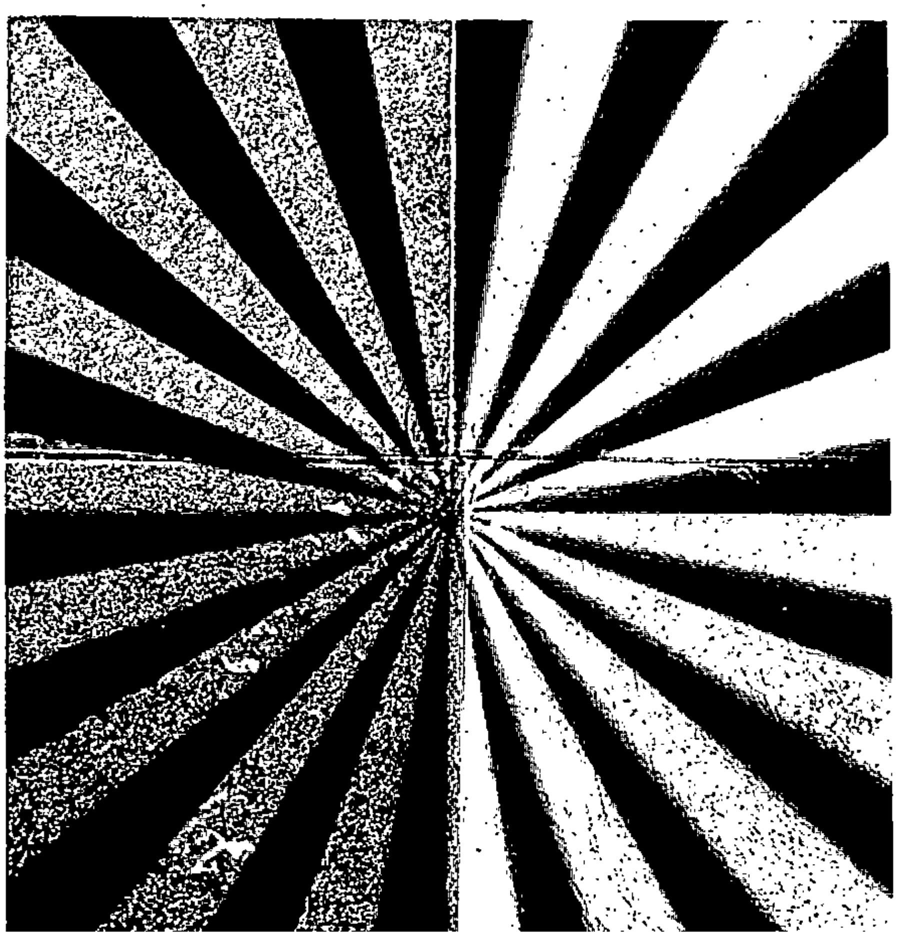


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Table II

Summary of the Optical Properties of Some Commercial Rear Projection Screen Materials

| Sample Code | $T_s$ % | $T_{45}$ % | Axial Gain | Brightness Variation $\pm 45^{o}$ (%) | K* | Improvement Possible (%) |
|---|---|---|---|---|---|---|
| DA-TEX | 53. | 34. | 8.2 | 77.6 | .50 | 100 |
| SN-2148 | 64. | 62. | 65. | 99.1 | .71 | 41 |
| SN-2149 | 43. | 17. | 1.2 | 3.9 | .78 | 29 |
| HI TRANS | 78. | 44. | 25. | 90.8 | .50 | 100 |
| S 50R | 70. | 31. | 3.7 | 40.9 | .69 | 44 |
| LS 40FM | 48. | 30. | 5.8 | 70.2 | .52 | 91 |
| OC 50FM | 83. | 51. | 10. | 69.4 | .68 | 47 |
| OC 70FM | 92. | 61. | 20.0 | 84.4 | .72 | 39 |
| LS 40-120 | 93. | 50. | 6.4 | 49.3 | .82 | 22 |
| LS 60-120 | 68. | 40. | 6.8 | 64.1 | .65 | 55 |
| LS 60FM | 59. | 33. | 4.9 | 57.5 | .63 | 59 |
| LS 60BFM | 68. | 42. | 11. | 78.4 | .56 | 80 |
| LS 60G | 38. | 25. | 3.8 | 64.0 | .56 | 80 |
| LS 60NG | 48. | 34. | 5.5 | 70.1 | .61 | 65 |
| LS 60PL | 55. | 40. | 6.0 | 66.7 | .67 | 50 |
| LS 60STG | 35. | 27. | 5.8 | 80.8 | .46 | 118 |
| LS 60VR | 59. | 43. | 8.8 | 78.5 | .62 | 62 |
| LS 75G | 61. | 52. | 29. | 95.4 | .59 | 69 |
| LS 85PL | 75. | 67. | 77. | 98.1 | .76 | 31 |
| LUX 50 | 54. | 39. | 10. | 84.2 | .53 | 91 |
| LUX 70 | 60. | 37. | 6.2 | 66.7 | .61 | 67 |
| RAVEN | 56. | 33. | 5.0 | 58.7 | .65 | 54 |
| TR 50PL | 60. | 27. | 2.4 | 23.8 | .78 | 28 |
| TR 80G | 91. | 80. | 27.0 | 92.3 | .91 | 9.6 |
| Type 1 | 82. | 70. | 23. | 89.9 | .79 | 20 |
| Type 4 | 28. | 24. | 6.7 | 89.9 | .38 | 166 |
| VCA 3606 | 78. | 37. | 37. | 92.7 | .42 | 138 |

*K = $T_{45}$ (Experimental)/$T_{45}$ Theoretical, Figure 3

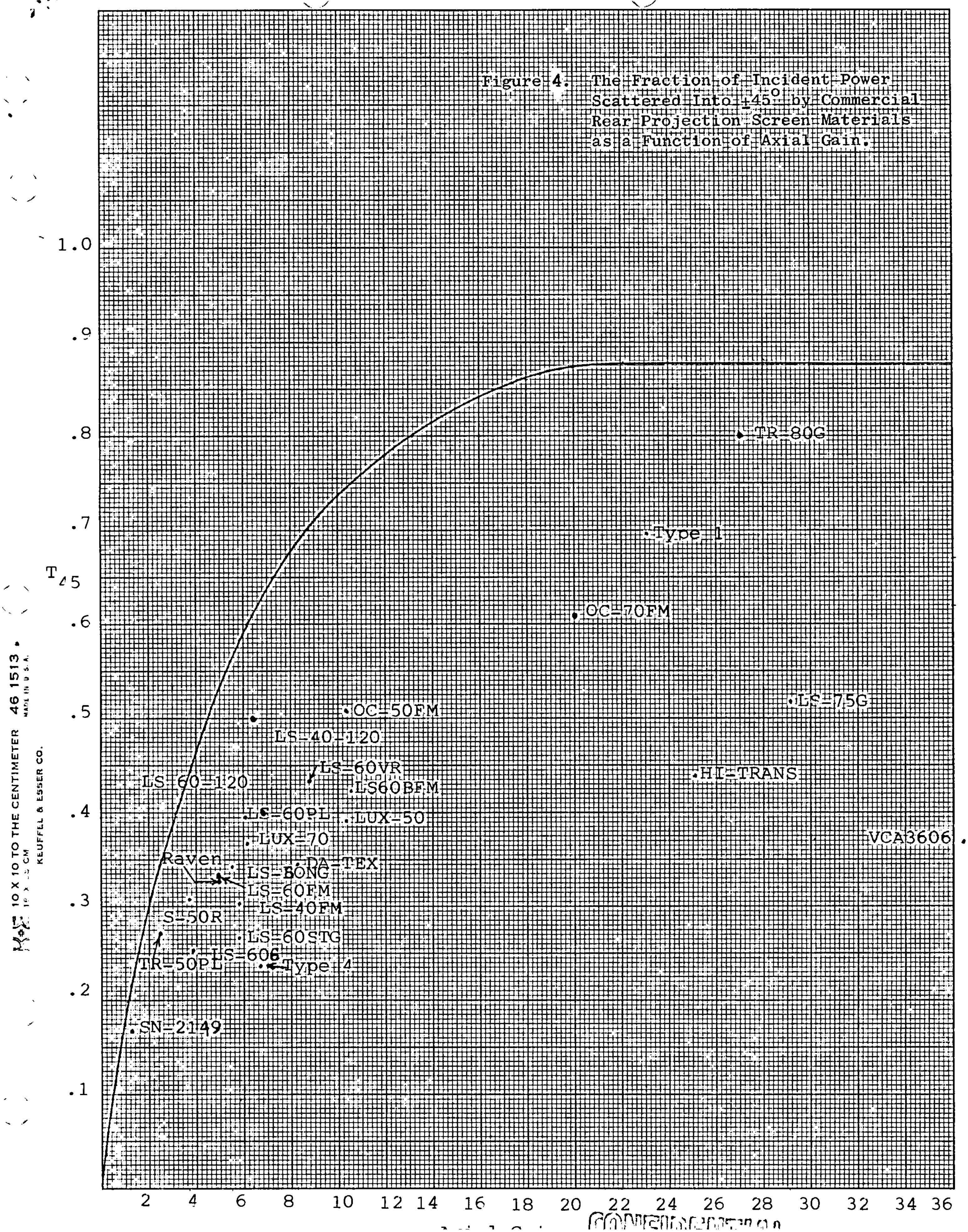


Figure 4. The Fraction of Incident Power Scattered Into $\pm 45^{o}$ by Commercial Rear Projection Screen Materials as a Function of Axial Gain.